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TRENCH STUDY OF THE SLIP RATE OF THE RAYMOND FAULT, SAN GABRIEL VALLEY

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The Raymond fault is a 20-km-long, left-lateral strike-slip fault that extends east-north-eastward through the San Gabriel Valley, northeast of downtown Los Angeles (Figure 1). The Raymond is one of several strike-slip faults that lie at the heart of a controversy concerning the mechanism of plate boundary deformation in the greater Los Angeles metropolitan area. Walls et al., (1998) have proposed that a significant percentage of north-south shortening across the region is accommodated by east-west extrusion of major crustal blocks along east-northeast left-lateral faults (e.g. Raymond, San Jose) and west-northwest trending right-lateral and oblique-reverse faults. In contrast, Argus et al., (1999) suggest that almost all north-south shortening is accommodated on east-trending contractional faults (e.g. Sierra Madre-Cucamonga). The extrusion model would therefore predict faster rates of strike-slip, whereas the contractional model would predict much slower rates of strike-slip.

In order to test these competing hypotheses, we excavated a 3-D network of more than 25 trenches and incrementally excavated trench faces across the Raymond fault at a site along the Southern California Edison power line right-of-way in eastern Pasadena (Figure 2). The site was identified on the basis of an examination of earlier maps of the Raymond fault (Buwalda, 1940; Crook et al., 1987; Weaver and Dolan, 2000), together with our field work and analysis of 1928-1952-vintage air-photos. This site was chosen because: (1) a previous trench excavated across the site provided evidence of both well-defined stratigraphy, including gravel channels, and a narrow zone of faulting (R. Crook, unpubl. data); (2) active drainages in the area cross the fault at a high angle; (3) the ground surface at the site is largely undisturbed (i. e., no removal of recent sediments); and (4) there was sufficient space in the Southern California Edison right-of-way to excavate a 3-D trench network.

Our excavations exposed a 10-m-wide zone of closely spaced sub-parallel faults, with a single 10-cm-wide main strand near the southern end of the zone (Figure 2). We traced in 3-D the buried western margin of a distinctive southward-flowing, >8-m-wide, pebble- and cobble-filled gravel channel that is offset by the fault (Figure 3). The 3D channel geometry exposed in the trenches shows that the channel flowed southward almost exactly perpendicular to the fault. In our 3D excavations, we were able to trace the channel edge directly into the main fault from both directions. These excavations reveal that the channel was cleanly offset by the fault, and was not diverted along the fault, showing that all of the apparent offset is a result of fault slip (Figure 2). Forty-two meters of the total channel offset of 44 +/- <~1m is accommodated on the main strand of the fault. A single AMS 14C date of a charcoal fragment obtained from a silty sand into which the offset channel was incised yielded a radiocarbon age of 25,400+/-160 yBP (~ 29,000 calendric years ago; Voelker et al., 1999). These observations yield a minimum left-lateral slip rate for the Raymond fault of 1.5 mm/yr. Fourteen additional charcoal samples, currently being AMS dated at the university of Arizona, and seven OSL (Green Light Stimulated Luminescence) samples being dated at the University of California--Riverside, will allow us to refine our maximum and minimum slip rate estimates for the Raymond fault.

The faulting observed in our 3D trench network is almost pure left-lateral strike-slip, with <50 cm of north-side-down vertical separation of deposits below the offset channel.

This observation is supports earlier suggestions by Jones et al (1990) and Weaver and Dolan (2000) that motion along the Raymond fault is almost purely left-lateral strike-slip, and that the pronounced south-facing scarps that mark parts of the fault trace are mainly a response to motion through a major restraining bend in southwestern Pasadena, as well as through several smaller fault bends. Our data indicate that significant left-lateral motion is occurring along the Raymond fault, consistent with either: (1) active westward extrusion of the Santa Monica Mountains block; and/or (2) transfer of slip westward from the Sierra Madre fault to the Verdugo-Eagle-Rock fault. The minimum slip rate we derive provides a critical constraint for any future kinematic models of deformation in Southern California. Weaver and Dolan (2000) suggest an average recurrence interval for Raymond fault surface ruptures of ≤~3 ky. If correct, this RI, combined with our minimum slip rate, suggests that Raymond fault surface ruptures are characterized by large offsets (~ 4-5 m). This, in turn, implies that these would be large-magnitude events (Mw > 7). If such large events do characterize the Raymond fault, then we speculate that they may involve simultaneous rupture of the Raymond fault together with the Hollywood-Santa Monica fault system to the west. Alternatively, many (most ?) paleo-surface ruptures on the Raymond fault must be missing from the paleoseismological record.

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Weaver, K. D., and Dolan, J. F., 2000, Paleoseismology and geomorphology of the Raymond fault, Los Angeles County, California: Bull. Seism. Soc. Amer., v. 90, p. 1409-1429.

Figure Captions

Figure 1. Regional neotectonic map for metropolitan southern California showing major active faults. Raymond fault shown in orange. Red triangle denotes location of East Pasadena trench site. After Dolan and others (1997).

Figure 2. Map of East Pasadena trench site showing locations of all trenches and incrementally excavated trench faces, as well as the known extent of the offset channel deposit (shown in brown).

Figure 3. Representative trench exposures of the offset channel deposit (shown in orange), from Face F (north of fault) and Face P-north wall (south of fault). See Figure 2 for locations.

Recent SCEC Publications (abstracts excluded) (** denotes student co-author under my primary supervision):

Dolan, J. F., Stevens, D.**, and Rockwell, T. K., 2000, Paleoseismologic evidence for an early to mid-Holocene age of the most recent surface rupture on the Hollywood fault, Los Angeles, California: Bulletin of the Seismological Society of America, v. 90, p. 334-344.

Weaver, K. D.**, and **Dolan, J. F.**, 2000, Paleoseismology and seismic hazards of the Raymond fault, Los Angeles County, California: Bulletin of the Seismological Society of America, v. 90, p. 1409-1428.

Dolan, J. F., Sieh, K., and Rockwell, T. K., 2000, Late Quaternary activity and seismic potential of the Santa Monica fault system, Los Angeles, California: Geological Society of America Bulletin, v. 112, p. 1559-1581.

Tucker, A. Z.**, and **Dolan, J. F.**, in press, Paleoseismologic evidence for a >8ka age for the most recent surface rupture on the eastern Sierra Madre fault, northern Los Angeles metropolitan region: Bulletin of Seismological Society of America, April 2001 Issue.

Hartleb, R. D.**, **Dolan, J. F.**, Akyuz, S., Dawson, T. E., Tucker, A. Z.**, Yerli, B., Rockwell, T. K., Toraman, E., Cakir, Z., Dikbas, A., Altunel, E., in review, Surface rupture and slip distribution along the Karadere segment of the 17-August-1999 Izmit, Turkey, earthquake: Bulletin of the Seismological Society of America, Special Issue on the 1999 Izmit and Duzce,Turkey, Earthquakes, N. Toksoz (ed.).

Harris, R., **Dolan, J. F.**, Hartleb, R. D.**, and Day, S., in review, Dynamic rupture model of the August 17, 1999, Izmit, Turkey, earthquake: Bulletin of the Seismological Society of America, Special Issue on the 1999 Izmit and Duzce,Turkey, Earthquakes, N. Toksoz (ed.).